Agrobiotechnology in developing countries

North–South partnerships are the key

Eric Tollens, Matty Demont and Rony Swennen

Abstract: *Agricultural production almost needs to double in the twenty-first century, putting tremendous pressure on agricultural resources. Most food production increases must come from more agricultural intensification in the South. This advances the need for a new green revolution: higher productivity and at the same time less pressure on the environment. Agrobiotechnology can contribute to this double green revolution. Biotechnology innovations are often scale-neutral and are therefore suitable for small farmers. Moreover, genetic modification offers special advantages for crops that have been domesticated for a very long time and which are therefore quite different from their wild relatives. However, agrobiotechnology also engenders risks and dangers, outlined in the paper. Multinational companies show little interest in small developing countries because the market is small and intellectual property rights protection is not effective. Not surprisingly, these are the very countries where food insecurity problems are most acute. In many developing countries the capacity to conduct biotechnology research and development is lacking, as is the legal framework for biosafety testing, patent enforcement and release of transgenic crops. This is illustrated by a case study on transgenic plantain bananas, developed by the Catholic University of Leuven, Belgium. The authors argue that legal and research capacity building are the main priorities. These can be achieved through public–private and North–South partnerships.*

Keywords: *agricultural biotechnology; developing countries; biosafety; capacity building; plantain banana; North–South partnerships*

Eric Tollens is a professor at the Center for Agricultural and Food Economics, Catholic University of Leuven (KU Leuven), W. de Croylaan 42, 3001 Leuven (Heverlee), Belgium. E-mail: eric.tollens@agr.kuleuven.ac.be. Matty Demont is a doctoral researcher at the Center for Agricultural and Food Economics, KU Leuven. Rony Swennen is a professor at the Laboratory of Tropical Crop Improvement, KU Leuven, Kasteelpark Arenberg 13, 3001 Leuven (Heverlee), Belgium.

The world population is expected to increase by half, ie from six billion in 2000 to about nine billion by 2100. By then, it is expected that the world population will have stabilized, and that the demographic transition will have run its full course. There is still a lot of debate concerning the level at which the population will stabilize, because of aid and other reasons. For food production just to keep pace with population growth, a 50% increase is required by the end of the twenty-first century. However, this would overlook the current food-insecure population, estimated at roughly 800 million (FAO, 2001). Most of the increase in food production is needed in the South, as over 90% of world population increase will take place there (Christiaensen and Tollens, 1995; Tollens, 1998).

Agricultural production almost needs to double in the twenty-first century (Evans, 1998) also because per capita animal protein consumption is expected to increase by half in developing countries. This requires a drastic increase in cereal and legume production, which is the basis for animal protein production (Tollens, 1999; Ballenger *et al,* 2001; Delgado *et al,* 1999; McCalla and Revodero, 2001; UNFPA, 2001). The increase in meat consumption is due to a universal desire to diversify the diet and eat meat, dairy products and fish (increasingly more from aquaculture) when per capita income increases. One example of this is China, where consumption of animal protein has doubled over the last two decades and is still growing. China is already the largest pig producer in the world, and India, known for its large vegetarian population, became the largest global milk producer in the 1990s (Tollens, 1999).

These trends put tremendous pressure on agricultural resources and reveal the spectre of the Malthusian doomsday (Malthus, 1966), with large-scale famines, and wars fuelled by the pursuit of agricultural land and/or irrigation water. The ultimate test of Malthus' prophesy is due in the twenty-first century. However, most agricultural scientists are confident that the world's population can be adequately fed, and that most food can be produced locally, ensuring the livelihood of farmers and food processors. This requires that agriculture, more than ever before, relies on science and technology, with agricultural intensification as the route to meeting mankind's food and fibre needs. This also implies that agricultural resources must be used in a sound, sustainable way, are less subject to biotic and abiotic stresses, and fit into local conditions.

Yield growth rates slowed during the period 1987–2001 (Evenson and Gollin, 2003). Soil erosion, declining soil fertility, pests and diseases, water shortages, etc, have contributed to pressures on the environment and resource base. Thus, the twenty-first century needs another green revolution to accelerate global food production (Conway, 1999).

Agrobiotechnology can contribute to the double green revolution, ie a higher yield with less pressure on the environment. In addition, agrobiotechnology holds the prospect of improved nutrition: better digestibility, improved nutrient content, including micronutrients, and fewer anti-nutritional factors. In what follows, it will become clear that we are only at the start of the biotechnology revolution.

Biotechnology and other agricultural technologies

Most food production increases must come from more agricultural intensification in the South (IFAD, 2001). This will result in higher and/or more stable yields, and will require more externally procured inputs such as improved seeds, organic and inorganic fertilizers, pesticides, machines and associated agricultural credit to pay for these inputs. Also, irrigation needs to increase drastically, particularly in Sub-Saharan Africa and Latin America. Irrigation is however an expensive technology, requiring about Euro 10,000 per ha. Moreover management of irrigation schemes is complex, as the numerous failures illustrate.

Usually combined improved technologies result in the highest pay-offs and yield increases because of synergistic effects. For example, improved, high-yielding seeds need better soil fertility management, integrated pest management, adequate post-harvest care and improved marketing to produce quantum leaps in productivity and incomes. This was the case with the green revolution in Asia in the 1960s–70s, which only took place in irrigated agriculture, on the best soils, and with only two crops, ie rice and wheat (Evenson and Gollin, 2003). Thus biotechnology[1] by itself, which results in a better genetic make-up of a crop or animal, is not sufficient to solve food production problems. It must be part of an improved farming system, in which the other required agricultural inputs and management practices are favourable, for the full expression of genetic potential. In addition, one has to consider the whole livelihood, including input distribution, agricultural marketing and non-farm income. Despite these complications, biotechnology is more attractive than any other technology because biotechnology provides a new package through the planting material, thus facilitating integration into the traditional smallholder farming systems (Qaim and Zilberman, 2003). Moreover, crops can be improved in a much more focused way.

Strengths of biotechnology

Biotechnology[2] offers new prospects because new crops can be developed at a faster pace and new avenues are opened for sterile crops. In short, genes of interest are inserted into the genome of a target plant to confer a new characteristic on that plant. This gene is then either expressed constitutively (always) or can be induced (activated) under certain conditions, such as, for example, pathogen attack. Biotechnology is also attractive for crops that are cross-bred because it avoids time-consuming backcrossing. Until recently, heterologous genes (genes from species other than the target species) were routinely used. However, with fast progress in genomics and bioinformatics, more homologous genes are now being identified. Performance of transformation protocols are so efficient and molecular tools of verification so fast that new plants can be created and evaluated rapidly, so that more transgenic plants than before can be created, thereby increasing the choices for identifying the best genotypes. Bioassays have also improved so that roughing efficiency under laboratory and glasshouse conditions has increased. In consequence, a fraction of the genetically engineered plants make it to the field and are moreover much better characterized.

Many important characteristics such as yield, plant architecture, or the ability to fix nitrogen through symbiosis with bacteria, are multigenic. This complicates their use, but science is advancing well. The production of Golden rice (rice expressing high levels of provitamin A) (Dawe *et al*, 2002) is a major milestone because it illustrates that complex biochemical pathways can be expressed in new plants. Currently however, cultivated genetically modified (GM) crops express only one or a few 'foreign' gene(s), which provide an agricultural advantage, such as herbicide tolerance, or insect resistance. Crops with two foreign genes ('stacked genes') of agronomical importance, such as herbicide tolerance and insect resistance (*Bt*) are now coming on to the market.

Insect resistance often comes from inserting a gene coding for the toxin, *Bacillus thuringiensis* (*Bt*). *Bt* toxin is very specific, which makes it safe to use, and its ingestion will kill some insects or at least slow down their development. The toxin is moreover biodegradable (EPA, 2000, 2001).

Insect resistance is particularly important against insects that are difficult to kill with insecticides because they hide inside the plant, such as with the European corn borer. This stem borer is important in southern Europe (Spain) and in the USA. Another example is the cotton bollworm borer, which lives inside cotton bolls, and cannot be killed easily by contact insecticides. Cotton is usually sprayed 5–10 times per growth cycle against the bollworm and other insects. Without spraying, the whole cotton harvest is usually lost. Hence insect resistance represents a major achievement, as only one or two sprayings are needed. In China, work is under way to develop insect-resistant rice (Santaniello, 2003).

In developing countries, *Bt* cotton can increase yields up to 80–87%, as in India (Qaim and Zilberman, 2003). In Kwazulu-Natal, South Africa, the average yield increase of *Bt* cotton over two years was 61% (Thirtle, 2003).

Herbicide tolerance allows total weed control by spraying once or at most twice with a total herbicide (eg Roundup®, Basta®). All plants except the GM plant are then killed. This reduces costs of weed control and is a bonus for the environment, as otherwise 3–5 applications are needed. In addition, farmers have more flexibility in timing herbicide application (Gianessi and Carpenter, 2000).

Many plants have recently been developed with resistance against fungi or viruses. Other GM plants are drought-tolerant, cold-tolerant, salt-tolerant, have a higher or modified nutrient content, etc. These plants need further investigation before they can be cultivated.

Biotech innovations are scale-neutral and are therefore suitable for small farmers. In addition, the genetic modification of many (sub)tropical smallholder crops has been started (Ortiz, 1998; Sharma *et al*, 2000; Swennen, 2002). Examples are tobacco, tomato, potato, pigeon pea, maize, sugar cane, rice and cotton (Falck-Zepeda *et al*, 2000). Of these, maize, potato and cotton are already under commercial production. Strategies have been developed for the genetic modification of cassava (against bacterial blight and African cassava mosaic virus), cowpea (cowpea mosaic virus, pod borers), maize (cob rot, drought), sorghum (*Striga* or witchweed), but also to express multiple genes in specific tissues and only at specific times (Farnham and Pilcher, 1998). This also involves the incorporation of traits that are not always available in the genetic resources pool (Herrera-Estrella, 1999; Swennen *et al*, 1998) but this picture is changing (Wiame *et al*, 2000).

Genetic modification offers special advantages for crops that have been domesticated for a very long time and which are therefore quite different from their wild relatives. Examples are bananas and plantains, which rarely set seed and/or yam and cocoyam, which rarely flower. Many cultivated crops are polyploids and their cross-breeding is particularly difficult. Here again, genetic modification facilitates improvement.

The impact of a GM crop is substantially different in developed and developing countries. In a developed country it reduces costs, for example, with a *Bt* crop. Indeed, a *Bt* crop reduces the number of insecticide treatments without a noticeable effect on the yield. In contrast, in a developing country with low-input agriculture, a *Bt* crop ensures a decent harvest, which would otherwise have failed without spraying. The effect is thus a higher yield.

Problems with biotechnology

As with all new technologies, risks and dangers are perceived (Driesen and Beerlandt, 1994; Oxfam, 1999), but so far remain hypothetical. They are summarized as follows:

- Risk of invasiveness, ie spreading particular genes in the environment (Amman, 2001), thereby conferring unwanted superior characteristics to weeds ('super weeds') or gene flow into wild relatives (eg maize and theosinte in Mexico). The possibility exists for cross-pollinating crops (as against self-pollinating crops or sterile crops). So far there are no facts confirming that this will create a hazard.
- Risk of losing biodiversity, as more and more farmers grow the same 'superior' GM varieties commercialized by a handful of multinationals. This was also applicable to the green revolution.
- Risk of allergy or toxicity for humans and animals. There are many toxic plants in nature and some plants contain toxic substances, albeit in very low concentrations (eg potato, wheat and tomato). Some people are susceptible to allergens. Introducing foreign genes in cultivated plants or domestic animals can create unwanted side effects such as allergy. However, GM foods and food products do not inherently present more unintended toxic properties than those presented by conventional breeding practices (Crop Biotechnology Update, 2002; Lomborg, 2001) and plants existing in nature. There is no need for a fundamental change in established principles of food safety to evaluate GM food; nor is a different standard of safety required.
- Ethical problems: transfer of genes between species and even from plants to animals (and humans) and vice versa can be seen as unethical; genomics increasingly shows that many genes of different species are very similar (homologous) and that different species carry gene relicts of foreign species.
- Loss of farmer sovereignty and overdependence of farmers on seed and chemical companies.[3] Only a handful of large, multinational seed companies venture into GMOs, protected under strict patents. Once farmers are 'hooked' on their technology, they can extract high monopoly rents. Farmers buying GM technologies from these companies (seed + chemicals + instructions) need to sign a contract, which forces them to pay a technology fee, not to reuse or sell the seed, and to observe a refuge area with conventional seed (to reduce the risk of resistance development). This practice is however similar to the use of hybrid seeds in cereal farming.
- Loss of foreign markets: because of the GMO moratorium in the European Union since 1998, transgenic seeds for human use (corn, soy beans, canola) are not

imported. Yet they are allowed for industrial use or in animal feed, but this is bound to change too. EU legislation on GMOs requires labelling and separate processing. Even if DNA cannot be detected in the final product for human consumption, GMO-derived products are banned for human consumption (eg in sugar or vegetable oils). Thus, the USA, Argentina, South Africa, China and other countries growing GM crops on a large scale cannot export GM crops destined for human consumption to the EU. A 0.9% threshold is allowed and segregation and identity preservation are required in the processing of crops that may contain GMOs. This represents an additional cost for exporting countries that also grow GM crops.

- Greater dependence of the South on the North for seed supply and technologies. As most of transgenic technology is developed in the North by private companies, and is protected by patents, Southern countries become more dependent on goodwill and contracts with the private sector in the North. This is a situation similar to that in other technologies or products such as drugs, mining technology, oil industry technology, medical technology, machinery, etc. One thus needs to develop scientific capacity in the South through universities and research institutions so that they develop their own technologies and deal with technologies offered by the North. Only a few, especially large, developing countries follow this strategy.

The spread of GM crops in developing countries

GM crops have been grown commercially since 1995, initially in the USA and Argentina. There are now an estimated 58.7 million hectares of GM crops and the area has increased by more than 10% every year for the past six years (James, 2002). About 27% of the global transgenic crop area in 2002 was cultivated in developing countries where growth is now more than twice that in industrial countries of the North. China had the highest year-on-year growth, with a 40% increase in its *Bt* cotton area, now about 51% of the global cotton area of 4.1 million hectares.

In 2002, three developing countries grew transgenic crops for the first time: India, Colombia and Honduras. Nine developing countries now grow GM crops: Argentina, China, South Africa, India, Uruguay, Mexico, Indonesia, Colombia and Honduras. Almost all the GM crops were produced by Monsanto (Huang *et al*, 2002).

The average *Bt* cotton farmer in China has reduced pesticide sprayings against the Asian bollworm from 20 times for conventional varieties to six times per year for *Bt* cotton. The cost of production of *Bt* cotton is 28% of that of non-*Bt* varieties (Huang *et al*, 2002). China now spends over US$100 million per year on GM research, on about 20 different crops, as much as all the other developing countries together.[4] Within five years, it is expected that the Chinese government will spend over US$500 million on transgenics, often in partnership with Chinese and overseas private companies such as Monsanto. In China the public sector is driving the agrobiotechnology revolution and thus China can stand as a model for other developing countries.

Multinational companies show little or no interest in developing countries, except for the large and potentially powerful ones (China, India, Brazil). This is because patent protection in most developing countries is weak and expected financial returns low. If involved, a third party such as a government and/or an aid agency (particularly USAID) pays for the technology transfer and capacity building. Hence the risk that multinationals might control the seed chain in these countries is purely theoretical. On the other hand, these companies can seek patent rights on useful traits in landraces from these countries. Multinational companies are in fact only interested in those crops that are also important in industrialized countries, such as wheat, corn, rice, cotton, canola, etc. They are not interested in cassava, sweet potato, millet, plantains, etc, which are only grown in poor developing countries. In many cases, proprietary technology is meaningless, as most of these ‘orphan crops’ are propagated vegetatively.

There are about 50 developing countries, especially in Sub-Saharan Africa, with underinvestment in agricultural research, both by the public and private sector. Private sector involvement is low because the market is too small and the intellectual property rights protection not effective. Not surprisingly, those are also the countries where food insecurity problems are most acute (Santaniello, 2003). Innovative ways to overcome this institutional failure are needed.

A well functioning seed market is considered essential for the adoption of newly improved varieties. However, in poor countries, informal seed markets play an important role. This explains the success of the new cotton varieties, for which the seed is delivered to the farmer via the ginning mill.

For developing countries, one can conclude that governments and aid agencies need to take initiatives to involve multinational companies (and their technology) and determine the terms and conditions under which multinational companies can cooperate, as is the case in China.

Capacity development in developing countries

In many developing countries, the capacity to conduct their own biotechnology research and development is lacking, as is the legal framework for biosafety testing, patent enforcement and release of transgenic crops. Countries introducing GM planting material need to have a biosafety-control system for evaluation under laboratory conditions and confined facilities. They need to be able to test for toxicity, allergenicity, spread of pollen, etc. They also need to enforce international treaties on plant variety diffusion, biodiversity and international property rights (Union for the Protection of New Varieties of Plants – UPOV, Trade Related Aspects of Intellectual Property Rights – TRIPS, the Cartagena protocol, World Trade Organization – WTO).

Biosafety is thus emerging as the principal constraint on the release of GM plants in developing countries (Paarlberg, 2000; 2001). Most developing countries are also influenced by the moratorium in Europe, presuming that something must be wrong with the technology because Europeans are so suspicious of it. However, they seem not to realize that the European attitude is also driven by market protection. Hence it is clear that training and capacity development are needed to allow Southern countries to make their own judgments.

North–South partnerships needed to build up biotech

The importance of agrobiotechnology for the South and the lack of local capacity

It is clear from the foregoing that another green revolution is needed to increase food production, especially in the (sub)tropics. This green revolution needs to be 'doubly green', pertaining to increases in yield, yield stability and the enhancement of the environment. The next generation of transgenic crops should have definite consumer advantages: particularly in the South, crops with improved nutritional value are needed.

Priority crops for genetic modification are those that rarely or never set seed or have a poor seed germination capacity (eg yam, banana, cocoyam and sweet potato) and which are thus difficult to cross-breed. Breeding of polyploid crops is expected to benefit most because conventional breeding is slow. With the declining resource base, biodiversity in smallholders' fields is decreasing, resulting in more pests and diseases and imbalances in food supplies. Therefore genetic modification for disease resistance (eg in banana) or higher protein content (eg in sorghum) is certainly warranted (Swennen, 2002).

Since 1994, putative fungus-resistant transgenic plantains (a starchy banana) have been obtained at the Catholic University of Leuven, Belgium and analysed in partnership with scientists from the South (eg Cuba, Ecuador, India, Uganda, etc). Expressed proteins in fruits and feeding tests with rats have shown non-toxicity, hence these plants deserve to be field-tested in the tropics for resistance confirmation and biosafety evaluation. Contained fields and nurseries have been put in place, yet the transgenic plants have not been exported due to the absence of competent national authorities that could approve the request for import and risk-assessment studies (Sági *et al*, 1998, 2000). Clearly, the legal conditions are not yet in place in most tropical countries, which imposes unnecessary delays in the evaluation of the transgenic plantains and cultivation of resistant plantains by smallholders. This has occurred in spite of the ratification of the Cartagena Protocol and article 19(3) of the Convention on Biological Diversity – CBD (Convention on Biological Diversity, 1994). The objective of the Cartagena Protocol is to contribute to ensuring an adequate level of protection in the field for the safe transfer, handling and use of transgenics resulting from modern biotechnology.

This 10-year delay in field-testing transgenic plantains clearly highlights that legal and political conditions are not in place in poor developing countries to evaluate biotechnologies that can alleviate poverty and increase food security. There is therefore an urgent need to build biotechnology capacity in developing countries, both through participation in biotechnological research and through tackling legal issues.

The conflicting opinions regarding agrobiotech in developing countries illustrate a mix of ideology, politics, science and ignorance, and demonstrate that agrobiotech is often poorly understood. In developing countries, so much emphasis and focus are placed on risk and on the dangers of biotechnology (just as in Europe) that the potential of the technology is lost. Low-income countries should be empowered to make their own choices based on informed debate and their own risk–benefit calculations.

Intellectual property rights, biosafety testing and legal issues

The current generation of transgenic bananas and their testing, however, highlights some problems that need to be avoided in future. Some genes of agronomic interest were owned by the industry, and it took much effort by the Catholic University of Leuven before these genes could be used freely for plantain and cooking bananas. Therefore it is urgent that a mechanism is put in place whereby an authority at the global level will interact with the industry to negotiate access to protected technologies for developing countries. Negotiations should be built upon Articles 1 and 19(2) of the CBD (fair and equitable sharing of the benefits arising out of the utilization of genetic resources) and Article 16 (access and transfer of technology on a fair and equitable basis) (Convention on Biological Diversity, 1994). However, in the case of food production by smallholders, it is absolutely necessary that technologies are royalty-free and that the transgenic plants produced are allowed to be harvested, resown and distributed from farmer to farmer without any financial return to the industry (Swennen, 2002).

Public research should play an increased role and could include (Heisey *et al*, 2001) education and training of plant breeders; refining and testing methodology for variety selection; commitment to germplasm preservation and development; and attending to minor crops. Molecular breeding is a truly multidisciplinary endeavour in which it will be increasingly difficult and expensive to generate appropriate critical mass in all the essential elements required to build a functional team. Consequently, public–private partnerships and consortia will be vital. For example, many CGIAR centres (Consultative Group of International Agriculture Research) have embraced biotechnology for the smallholder within 'public good' principles of equity with regard to long-term impact and appropriate trusteeship of the ownership of genetic resources. However, its annual budget for biotechnology is $25–30 million, which cannot compare with private sector research spending. UNDP urges that there should be 'greater public investment in GMO research and development to ensure it meets the needs of the poor' (UNDP, 2001).

Critics claim that biotechnology will not benefit the tropics, but the following quote is particularly relevant:

> The prediction so often heard that the poor in developing countries are unlikely to benefit from modern biotechnology in the foreseeable future could well come true – not because the technology has little to offer but because it will not be given a chance (Per Pinstrup Andersen, former Director-General, IFPRI).

This is certainly caused by the fact that most research in the North is conducted on commercial crops/varieties and features of no value to the developing countries (male sterility in oilseed rape; herbicide tolerance in oilseed rape, sugar beet and maize; and insect resistance in potato and maize).

North–South partnerships needed to build up agrobiotech

From the foregoing, it is clear that the production of transgenic crops and biosafety testing are hampered tremendously by the lack of an adequate legal environment in developing countries, access to patented technologies, and local capacity to deal responsibly with agrobiotechnology. Agrobiotechnology in poor countries is a case of market failure, and (private) markets will not lead to an optimal use of the technology. There is thus a need for public interventions. But since agrobiotech expertise and patents are mainly in private hands in the North, public–private and North–South partnerships are needed to build up agrobiotech. Ideally, a three-way partnership is involved: the public sector (aid agency) in the North, the private sector in the North (multinational life science company) and the public sector in the South. In addition, collaboration between universities or research institutes on transgenics in the North and the South is needed for capacity building.

Conclusions

Biotechnology for agriculture in the South is neither the golden bullet nor an absolute necessity. But it is the best available technology for solving certain problems. Its greatest potential is in stabilizing yields at high levels by alleviating biotic and abiotic stresses. What biotechnology can do is best illustrated by the case of *Bt* cotton in China. It represents tremendous savings in terms of less insecticide use, higher yields and incomes, less toxicity for humans, and less risk overall. It is a case in which small farmers are benefiting greatly. Even in industrialized countries, about two-thirds of the benefits go to farmers, with added flexibility in operations. Unfortunately, consumers so far gain little, if anything, except through less use of pesticides/use of less toxic pesticides. The next generation of transgenic crops is expected to have definite consumer advantages in terms of better nutritional value or other positive product characteristics. This is also particularly important for developing countries.

What is lacking most in the South is the capacity to develop its own biotechnology strategies and applications, and to implement biosafety regulations and testing. International agreements and protocols of significance in this area are not much more than dead letters for most developing countries. It is clear that they will need assistance and collaboration from the North. In addition, so many misunderstandings and fiction are ongoing with agrobiotechnology, that the advantages and benefits cannot even be explored and thus are not exploited in the South. The misguided focus on the potential dangers of transgenic corn from the USA as food aid in Zambia and Zimbabwe, where thousands of people were on the brink of starvation, is a testimony to the mistaken beliefs and misguided perceptions that so many people have of biotechnology. For over six years now, Americans, Canadians and others have consumed large quantities of food prepared with GM crops and not one case of sickness, let alone death, has been reported.

In the medical field, one-third of our medicines are now derived from biotechnology applications, including insulin for diabetic patients, most of our antibiotics, hormones for therapy, etc. For medical cures, biotechnology is common practice, not questioned and fully accepted. However, for feeding humanity, there is much opposition. It is time that we trusted science and technology based on science, and focused on the bigger issues. For most poor countries in the South, this means alleviating poverty and food insecurity, and planning for the population increase that is bound to come during this century. Technology is one of the most powerful tools to achieve the goals of food security and poverty alleviation. Transgenic crops can help to ensure that an adequate food supply is available, and in the process of producing it, millions of poor farmers can make a living and may be lifted out of poverty. Of the 800 million poor and food-insecure in this world, 70% live in rural areas and find their livelihood rooted in agriculture. Biotechnology can help to increase their productivity and incomes. This chance should not be lost (Pinstrup-Anderson, 2001). Private markets alone will not lead to an optimal use of agrobiotechnology, and this is clearly a case of market failure, warranting public intervention.

But help will be needed from the North to build up a biotechnology capacity in the South, including biosafety regulations and protocols. Moreover, most of the investments in technology will have to be made by the public sector, as new plant varieties and seeds are still mainly a public good in most poor countries. Multinational companies cannot be expected to help on a large scale in developing countries, except if they are paid for technology transfer and capacity building. There are only a few large, technology-developing poor countries where multinationals have a genuine interest and where large private seed companies are already operating. For the real 'orphan' crops, the multinationals will probably never show real interest. Thus, governments from the North and the South need to enter into genuine partnerships and need to involve the private sector in the North to build up biotechnology capacity in the South and to tap the potential benefits of this technology for the poor and hungry of today, and particularly of tomorrow. Moreover, low-income people and countries should be empowered to make their own choices based on informed debate and their own risk–benefit calculation (Pinstrup-Anderson and Cohen, 2002). Differential environmental concerns between rich and poor countries are likely to lead to different perspectives on the use of modern biotechnology.

Notes

1 By biotechnology, we mean molecular biotechnology involving genetic engineering and the creation of transgenic plants. In our definition, beer brewing, fermentation, etc, or in vitro culture are not included.

2 Currently one can insert 12 genes simultaneously, conferring several characteristics on the target plant.

3 The rather negative attitude towards GMOs is partly the fault of multinational life science companies. In the early days of biotechnology they 'imposed' their technology rather than

offering it to 'takers' like any other technology. On the other hand, governments, particularly in Europe, developed accompanying policies and a regulatory framework much too late. The same risk exists now in developing countries.

[4] In particular, China invests in genomics projects, eg sequencing of the rice genome and field-testing a cold-tolerant tomato.

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